INFLUENCE OF PREHARVEST AND POSTHARVEST ENVIRONMENT ON NUTRITIONAL COMPOSITION OF FRUITS AND VEGETABLES.

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Fruits and vegetables are very important sources of vitamins, minerals, and dietary fiber. Their contribution as a group is estimated at 91% of vitamin C, 48% of vitamin A, and 27% of vitamin B_6, 17% of thiamin, and 15% of niacin in the American diet. Fruits and vegetables also supply 26% of magnesium, 19% of iron, and 9% of the calories (Goddard and Matthews, 1979). Legume vegetables, potatoes and tree nuts contribute about 5% of the per capita availability of proteins in the U.S., and their proteins are of good quality as to content of essential amino acids. Other important nutrients supplied by fruits and vegetables include folacin, riboflavin, zinc, calcium, potassium, and phosphorus.

Many pre- and postharvest factors influence the composition and quality of horticultural crops (Hulme, 1971; Nagy and Shaw, 1980; Pattee, 1985). The varietal influence on nutritional value of fruits and vegetables has been reviewed by Stevens (1974) and Harris (1975), who provided several examples of the large genotypic variation in vitamin content. Other preharvest factors include: (1) cultural conditions such as: soil type, nutrient and water supply, rootstocks, mulching, pruning, thinning, and use of agricultural chemicals, and (2) climatic conditions such as: temperature, light, wind, rainfall, and pollutants. All these factors are responsible for the wide variation in nutritional quality of fruits and vegetables at harvest which makes nutritional labeling of these commodities near impossible.

Maturity at harvest, harvesting method,and postharvest handling conditions (time between harvest and consumption, extent of physical damage, temperature, relative humidity, atmospheric composition, and various postharvest treatments) also affect the nutritional quality of fruits and vegetables. Some of these factors as well as processing methods (blanching, canning, drying, freezing, etc.) and cooking procedures can result in significant losses of certain nutrients (Fennema, 1977; Goddard and Matthews, 1979; Kramer, 1974 and 1977; Krochta and Feinberg, 1975; Salunkhe et al., 1973; White and Selvey, 1974; Yamaguchi and Wu, 1975).

Water-soluble vitamins (vitamin C, thiamin, riboflavin, niacin, vitamin B_6, folacin, vitamin B_{12}, biotin, and pantothenic acid) are much more susceptible to postharvest losses in fruits and vegetables than fat-soluble vitamins (vitamins A, D, E, and K). Vitamin C (ascorbic acid) is most sensitive to destruction when the commodity is subjected to adverse handling and storage conditions and it is used as an index to the stability of other nutrients. Losses are enhanced by extended storage, higher temperatures, low relative humidity, physical damage, and chilling injury. Postharvest losses in other vitamins may occur due to degradation at high temperatures in the presence of oxygen.

This chapter includes a brief overview of how preharvest conditions, harvesting, and postharvest handling procedures influence the nutritional composition (especially vitamins and minerals) of fresh fruits and vegetables.

Kader, A.A. 1988. Influence of preharvest and postharvest environment on nutritional composition of fruits and vegetables, p. 18-32. In: B. Quebedeaux and F.A. Bliss (Eds), Horticulture and Human Health, Contributions of Fruits and Vegetables. Prentice-Hall, Englewood Cliffs, N.J.

Climatic Conditions. Climatic factors, especially temperature and light intensity, have a strong influence on the nutritional quality of fruits and vegetables. Consequently, the location and season in which plants are grown can determine their ascorbic acid, carotene, riboflavin, and thiamin content. Light is one of the most important climatic factors in determining ascorbic acid content of plant tissues (Somers and Beeson, 1948). Harris (1975) reviewed the work of many researchers on the role of environmental factors in determining nutritional composition. He concluded that the amount and intensity of light have an effect upon the composition of plants, especially on the content of ascorbic acid. We consistently find much higher ascorbic acid content in strawberries grown under conditions of greater light intensity than in fruits of the same varieties produced under lower light intensity conditions. In general, the lower the light intensity, the lower the ascorbic acid of plant tissues.

While light does not play a direct role in the uptake and metabolism of mineral elements by plants, temperature influences the nutrient supply because transpiration increases with higher temperatures. Rainfall effects the water supply to the plant, which may influence composition of the harvested plant part.

Air pollutants, such as ozone peroxyacetyl nitrate, do not have a major and generally deleterious impact on crop composition. The responses to these pollutants vary among crops. Pippen et al. (1975) investigated the effects of exposure to 200 and 350 ppb ozone on composition of several vegetable crops. Ozone had no or a slight effect on contents of vitamins and minerals in strawberries, but it resulted in higher ascorbic acid and thiamin content in cabbage and the opposite effect was found in tomatoes.

Cultural Practices. Soil type, rootstock used for fruit trees, mulching, irrigation, and fertilization influence the water and nutrient supply to the plant, which can affect the nutritional composition of the harvested plant part. Somers and Beeson (1948) conclueded that the effect of fertilizers on the vitamin content of plants is much less important than the other variables such as variety and climate, but their effect on mineral content is more significant. Lee (1974) and Harris (1975) reviewed the voluminous literature relating to the effects of soils and fertilizers upon the nutrient content of plants and concluded that while fertilizers increase the crop yield, their effect on vitamin content is minor and usually insignificant.

Augustin (1975) found that the response of ascorbic acid values in freshly harvested potatoes to nitrogen fertilization depends on the variety but the general trend is for a decrease in ascorbic acid content with increasing amounts of nitrogen fertilizer used. Increasing the nitrogen and/or phosphorus supply to citrus trees results in somewhat lower acidity and ascorbic acid content in citrus fruits, while increased potassium fertilization increases their acidity and ascorbic acid content. (Nagy, 1980). Irrigation as presently practiced has not been shown to be a dominating factor in determining quality of fresh citrus fruits (Reitz and Embleton, 1986).

Cultural practices, such as pruning and thinning determine the crop load and fruit size, which can influence nutritional composition of fruits. The use of agricultural chemicals, such as pesticides and growth regulators does not directly influence fruit composition but may indirectly affect it due to delayed or accelerated fruit maturity.

Maturity at Harvest. This is one of the main factors which determine compositional quality and storage-life of fruits and vegetables. All fruits, with few exceptions, reach peak eating quality when fully ripened on the tree. However, since such ripe fruits cannot survive the postharvest handling system, they are usually picked mature but not ripe. Kader et al. (1977) found that tomato fruits harvested green and ripened at 20°C to table ripeness contained less ascorbic acid than those harvested at the table-ripe stage. Betancourt et al. (1977) reported that 'Ace 55' tomato fruits analyzed at the "breaker" stage contained only 69.2% of their potential ascorbic acid concentration if ripened on the vine to table-ripe. Fruits accumulated ascorbic acid during ripening on or off the plant, but the increase was much greater for those fruits left on the plant.

Ascorbic acid content increased with ripening in apricots, peaches, and papayas, but decreased in apples and mangoes (Table 1). Lee et al. (1982) reported that larger and more mature peas contained less ascorbic acid and carotene, but more thiamin than smaller and immature peas.

Table 1. Effect of maturity stage on ascorbic acid content of some fruits

Fruit & Cultivar	mg Ascorbic Acid/100 g (FWB)		
	Green	Half-ripe	Ripe
Apple (Baldwin)	18.7	18.5	12.4
Apricot (Tilton)	11.7	12.9	14.3
Peach (Elberta)	7.8	10.2	12.2
Mango (Pirie)	60	50	14
Papaya (Solo)	72	95	102

Adapted from: Zubeckis (1962) and Wenkam (1979).

Both ascorbic acid and total carotenoids (beta carotene or provitamin A is predominant) increased with maturation and ripening in clingstone peaches (Table 2). Nagy (1980) reported that although vitamin C concentration decreased during maturation of citrus fruits, the total vitamin C content per fruit tended to increase because the total volume of juice and fruit size increased with advanced maturity.

Table 2. Effect of maturity at harvest on ascorbic acid and total carotenoids of clingstone peaches

Cultivar	Maturity Stage	mg 100 g (FWB)	
		Ascorbic Acid	Total Carotenoids
Andross	M-1	10.7	2.2
	M-2	12.2	2.4
	M-3	13.2	2.7
Halford	M-1	8.8	1.7
	M-2	11.7	2.0
	M-3	13.7	2.0

Adapted from: Kader et al., 1982.

Harvesting Method. The method of harvest can determine the extent of variability in maturity and physical injuries, and consequently influence nutritional composition of fruits and vegetables. Mechanical injuries such as bruising, surface abrasions, and cuts can result in accelerated loss of vitamin C. The incidence and severity of such injuries are influenced by method of harvest used management of the harvesting, and handling operations. Proper management to minimize physical damage to the commodity is a must whether harvesting is done by hand or by machine. Strawberries and other berries lose vitamin C quickly during postharvest handling if capped or bruised during harvesting (Ezell et al., 1947). Mondy and Leja (1986) found a very large decrease in ascorbic acid content of the bruised tissue of potato tubers, while the unbruised halves appeared to show an increase in their ascorbic acid content.

POSTHARVEST FACTORS

Orderly marketing of fresh fruits and vegetables involves their transport between production area and consumption point which may be a few, or several thousand, miles away. Temporary holding or long-term storage may also be necessary for many fresh fruits and vegetables. Most processing commodities are used soon after harvest, but they may be stored for some time prior to canning, freezing, pickling, etc., to suit the operating capacity of the plant. In all cases, proper postharvest handling procedures are essential for extending shelf-life and maintaining quality of fresh produce.

Fresh fruits and vegetables as living tissues are subject to continual changes after harvest. Such changes cannot be stopped but can be controlled within certain limits by using various postharvest procedures. In general, freshly harvested fruits and vegetables contain more vitamins than those held in storage. Nutrients begin to be lost as soon as fruits and vegetables are harvested. Because of their very high water content, fresh fruits and vegetables are subject to desiccation and mechanical injury. They are also susceptible to pathological breakdown. The following procedures are currently used to slow down the deterioration rate of harvested horticultural commodities.

I. Temperature and Relative Humidity Management Procedures

Temperature management is the most important tool that we have to extend shelf-life and maintain quality of fresh fruits and vegetables. Above the freezing point, for non-chilling-sensitive commodities, every increase in temperature of 10°C accelerates deterioration and increases the rate of loss in nutritional quality by 2- to 3-fold. This is also true for chilling-sensitive commodities at temperatures above their minimum safe temperature of 5 to 13°C, depending on the commodity. Exposure of these commodities to temperatures below their minimum safe temperature causes chilling injury and faster deterioration upon transfer to higher temperatures.

Delays between harvesting and cooling or processing can result in direct losses (due to water loss and decay) and indirect losses (partial lowering of flavor and nutritional quality). The extent of such losses is related to the condition of the commodity when picked, and is strongly influenced by the temperature of the commodity which can be several degrees higher than ambient temperatures, especially when exposed to direct sunlight. Kader and Morris (1978) found that delays of 24 hours at 30°C and 40°C between harvest and processing of tomatoes result in about 5 and 12% loss in ascorbic acid, respectively.

Proper temperature management begins with the rapid removal of field heat by using one of the following cooling methods: hydrocooling, in-package icing, top icing, room cooling, forced-air cooling, serpentine forced-air cooling, vacuum cooling, and hydro-vacuum cooling or evaporative cooling. After cooling, commodities should be stacked in the cold room leaving air spaces between pallets and room walls as well as among pallets to ensure good air circulation. Storage rooms should not be overloaded beyond limit for proper cooling. In monitoring temperatures, commodity temperature rather than air temperature should be used. Transit vehicles must be cooled before loading the commodity. Delays between cooling after harvest and loading into transit vehicles should be avoided. Proper temperature maintenance should be ensured throughout the handling system to wholesale and retail distribution centers and to the consumer's home.

All of these temperature management procedures are essential for not only the reduction in postharvest losses but also for maintenance of quality including nutritional (quality). Numerous investigators have demonstrated that temperatures higher than those which are optimum for the commodity result in increased loss rate of vitamin content especially vitamin C. Zepplin and Elvehjein (1944) found that leafy vegetables held at 6°C lost 10% of their ascorbic acid content in 6 days while those held at room temperature lost 20% in only 2 days. Losses in vitamin C (Table 3) and vitamin A (Table 4) in Kale were accelerated at higher temperatures (Ezell and Wilcox, 1959 and 1962); similar results were obtained with spinach, cabbage, and snap beans. In general, the extent of loss in ascorbic acid content in response to elevated temperatures is greater in vegetables than in fruits which are more acidic (pH = 4.0 or lower), such as citrus (Nagy, 1980)

Table 3. Effect of temperature and wilting on vitamin C loss in Kale.

Rate of Wilting	Average Loss % After 2 Days At		
	0°C	10°C	21°C
Slow	2.4	15.3	60.9
Moderate	3.8	15.8	69.6
Rapid	5.3	33.1	88.8

Adapted from: Ezell & Wilcox, 1959.

Table 4. Effect of temperature and wilting on vitamin A loss in Kale.

Rate of Wilting	Average Loss % After 4 Days At		
	0°C	10°C	21°C
Slow	0	17	59
Moderate	0	19	66
Rapid	5	31	76

Adapted from: Ezell & Wilcox, 1962.

Losses in nutritional quality increase with time and temperature of storage as shown for potatoes, as an example, in Tables 5 and 6. Also shown is the fact that ascorbic acid is lost much more readily than other vitamins.

Table 5. Effect of storage time on the content of some water-soluble vitamins in 'Russet Burbank' potatoes.

Storage Time (Days)	mg/100 g (DWB)			
	Ascorbic Acid	Thiamin	Riboflavin	Niacin
5	136.5	0.38	0.10	8.7
90	68.1	0.51	0.09	9.6
170	54.7	0.45	0.10	9.9
240	46.6	0.52	0.09	9.2

Adapted from: Augustin, 1975.

Table 6. Effect of temperature and time on vitamin content of 'Russet Burbank' potatoes.

Temperature and Duration	mg/100 g (DWB)					
	Ascorbic Acid	Thiamin	Ribo-flavin	Niacin	Folic Acid	Vitamin B_6
Initial	82.6	0.36	0.14	6.7	0.06	0.95
3.3°C, 4 wks	44.2	0.30	0.11	5.3	0.05	1.06
3.3°C, 8 wks	39.7	0.40	0.15	5.1	0.05	1.56
7.2°C, 4 wks	50.3	0.31	0.11	5.9	0.05	1.07
7.2°C, 8 wks	34.7	0.42	0.14	4.3	0.05	1.46

Adapted from: Augustin et al., 1978.

Chilling injury causes accelerated losses in ascorbic acid content of sweet potatoes, pineapples, and bananas, but it does not influence ascorbic acid content of tomatoes and guava fruits.

Relative humidity can influence water loss, decay development, incidence of some physiological disorders, and uniformity of fruit ripening. Condensation of moisture on the commodity (sweating) and not the relative humidity of ambient air can enhance decay and should be avoided. Proper relative humidity is 85 to 95% for fruits and 90 to 98% for vegetables except dry onions and pumpkins (70 to 75%). Some root vegetables can best be held under 95 to 100% rh.

Conditions favorable to wilting resulted in a more rapid loss of vitamins C (Table 3) and A (Table 4). Water loss (wilting or shriveling) is greatly influenced by both ambient temperature and relative humidity relative to commodity temperature and water potential.

II. Supplements to Temperature Management

Many technological procedures are used commercially as supplements to temperature management. None of these procedures, alone or in various combinations, can substitute for maintenance of optimum temperature and relative humidity in extending shelf-life of harvested fruits and vegetables. But they can help extend shelf-life beyond what is possible using refrigeration alone. Supplemental postharvest technology procedures include:

A. Treatments applied to the commodity:

1. Curing: Placing certain root vegetables under high humidity and high temperature results in healing of wounds and thickening of protective tissues which help reduce water loss and decay during subsequent storage.

2. Cleaning: Removal of dirt, dust, residue of agricultural chemicals, etc., through washing of the commodity can be beneficial to shelf-life provided that excess water is removed from the surface after washing. Chlorination of the washing water helps reduce bacterial count and permits its use for longer duration.

3. Sorting: Elimination of defects through sorting is essential to good initial quality and storage-life of any commodity. Sorting according to stage of maturity and ripeness is also important since shipping ability and storage-life of fruits depend on their ripeness (softness).

4. Trimming and cutting: Excessive trimming of leafy vegetables results in loss of outer green leaves which contain more vitamin A, calcium, and iron than inner leaves. Broccoli leaves have more vitamin A value than stalks or florets. Losses in vitamins A and C occur when vegetables are severely trimmed, cut, or shredded as in the case of cabbage, lettuce, carrots, and other vegetables sold as salad mixes. Green peas and green lima beans retain their nutrients better if left in their pods than if shelled. In contrast, a large increase in ascorbic acid content in potato slices (1 mm) and strips (10 x 20 mm) has been reported (Mondy and Leja, 1986).

5. Waxing: Covering fruits with various types of food-grade waxes or other surface coatings can help reduce water loss and improve appearance. The wax may also be used as a carrier for postharvest fungicides. Excessive waxing should be avoided because it can restrict gas exchange and result in anaerobic respiration (fermentation).

6. Heat treatments: Dipping certain fruits, e.g., stone fruits, cantaloupes, into hot water at 49 to 54°C for 2 to 3 minutes has been tested as a means of decay control. Since such treatments do not have any effect on subsequent attack by pathogens, their commercial use is very limited. Heat treatments for longer durations (40 to 60 minutes) may be used for insect control in harvested papaya and mango fruits to meet quarantine requirements. The effect of heat treatments on nutritional composition of fruits has not been evaluated.

7. Treatment with fungicides: Some chemicals such as Botran, Benlate, Sodium orthophenylphenate, and Imazalil, are added to certain fruits and vegetables for decay control. These postharvest fungicides are added separately or incorporated into waxes.

8. Use of sprout inhibitors: Maleic hydrazide can be used before harvest to inhibit sprouting of onions and potatoes during storage. Other sprout inhibitors such as CIPC may be used as dust for sprouting control on potatoes after harvest.

9. Special chemical treatments: Scald inhibitors may be used on apples and pears. Calcium dips may also be used to reduce physiological disorders and maintain firmness in apples and cherries. Bangerth (1976) observed an increase in vitamin C content of apples and tomatoes treated with calcium chloride.

10. Fumigation: SO_2 fumigation is used on grapes for effective decay control. Most other commodities are very sensitive to SO_2 injury. Methyl bromide, hydrogen phosphide, and other fumigants may be used for insect control to meet quarantine requirements of importing countries.

11. Irradiation: Ionizing radiation may be used for sprout inhibition, insect control, or delay of ripening of certain fruits and vegetables. Irradiation at doses that these commodities can tolerate does not reduce their caloric value or nutritional quality significantly. Only negligible losses in niacin, thiamin, riboflavin, and beta-carotene (provitamin A) have been attributed to irradiation. Ascorbic acid (vitamin C) is more radiosensitive, and its losses range from 0 to 95%, depending on the commodity, cultivar, irradiation dose, and duration and temperature of storage (Maxie and Abdel-Kader, 1966).

12. Ethylene treatment: Ethylene may be used commercially to degreen citrus fruits and to achieve faster and more uniform maturation and ripening of fruits such as bananas, tomatoes, honeydew melons, casaba melons, avocados, mangos, papayas, and persimmons. It is effective only if applied on fruits before ripening is initiated. If the fruits have already begun to ripen, they will produce their own ethylene and any added ethylene will be useless. A concentration of 100 ppm ethylene for 48 hours is generally adequate for most fruits. The optimum temperature range for this ripening treatment is 20 to 25°C with a relative humidity of 85 to 95%. Adequate air circulation within the room to ensure uniform distribution of the gas is important. It is also essential to ensure that CO_2 produced by the fruits does not accumulate in the room by using enough continuous air exchange or by opening the room for air change every 24 hours, then regassing. Watada et al. (1976) reported that ascorbic acid content was slightly higher in mature-green tomatoes treated with C_2H_4 than in those ripened without added C_2H_4. Kader et al. (1978) found a significant difference in ethylene-treated vs control mature green tomato fruits (Table 7). They concluded that the use of ethylene treatment to enhance ripening of mature-green fruits can be advantageous in shortening the duration between harvest and consumption, and in maintaining

a higher ascorbic acid content. Cantwell, Strand, and Morris (unpublished data) found consistently higher ascorbic acid content in tomato fruits subjected to C_2H_4 than in those kept in air and extent of this difference varied among genotypes. It appears that C_2H_4 may have a direct effect on synthesis and/or degradation of ascorbic acid.

Table 7. Effect of ethylene treatment on ascorbic acid content of tomato.

Treatment	mg Ascorbic Acid/100 g (FWB) When Ripe
Picked table-ripe	19.2
Picked mature-green ripened at 20°C	12.3
Picked mature-green, ripened with ethylene at 20°C	15.5

Adapted from: Kader et al., 1978.

B. Treatments involving manipulation of the environment:

1. Packaging: Use of moisture barriers, e.g., polyethylene liners in shipping containers and extent of container venting influence gas exchange and cooling efficiency. Use of packages which exclude light for potatoes helps in reducing greening (due to chlorophyll and solanine formation).

2. Air movement and circulation: The airflow rate and circulation within a storage room are important to temperature uniformity and may influence rate of water loss by the commodity.

3. Air exchange or ventilation: Introduction of fresh air into the storage room affects concentrations of O_2 and CO_2 and accumulation of ethylene and other volatiles.

4. Exclusion and/or removal of ethylene: Because of the wide range of detrimental effects of ethylene on most vegetables and fruits, it is very important to avoid their exposure to it. However, exposure to C_2H_4 may be beneficial in terms of increasing ascorbic acid content of certain fruits.

5. Modified/controlled atmospheres: Modified atmospheres (MA) or controlled atmospheres (CA) mean removal or addition of gasses resulting in an atmospheric composition different from that of air. This usually involves reduction of oxygen (O_2) and/or elevation of carbon dioxide (CO_2) concentration. MA and CA differ only in the degree of control; CA is more exact. Reduced O_2 and/or elevated CO_2 delays fruit ripening, reduces respiration and ethylene production rates, retards softening, and slows down all the compositional changes associated with ripening. These benefits of CA translate into extension of storage-life, maintenance

of quality, and reduction of postharvest losses.

Slowing down compositional changes means reduced rates of loss in nutritional quality as illustrated for ascorbic acid changes in spinach (Table 8) and apples (Table 9). Bangerth (1977) found reduced ascorbic acid losses in apples and red currants by storage in reduced O_2 atmospheres and accelerated ascorbic acid losses by storage in elevated CO_2 atmospheres. Storage for 6 days in CO_2-enriched atmospheres resulted in a reduction in ascorbic acid content of sweet pepper kept at 13°C (Wang, 1977) but an increase in its content in broccoli kept at 5°C (Wang, 1979). During subsequent storage of peppers in air at 13°C, differences in ascorbic acid content between CO_2-treated and control fruits became less significant and none were detected by the 20th day.

Table 8. Effect of CA on ascorbic acid content of spinach at 7.5°C.

Storage Time (Days)	mg Ascorbic Acid/100 g (DWB)	
	Control	4% O_2 + 9% CO_2
0	7.2	7.4
3	5.2	6.6
5	4.4	6.4
7	3.2	5.3

Adapted from: Burgheimer et al., 1967.

Table 9. Effect of CA on ascorbic acid content of apples at 15°C.

Storage Time (Days)	mg Ascorbic Acid/100 g (FWB)	
	Control	3% O_2
10	18.1	24.1
35	8.9	18.4
66	5.5	15.9
85	3.3	14.9

Adapted from: Delaporte, 1971.

In general, the lower the O_2 concentration during storage, the lower the losses in ascorbic acid and other vitamins in the various commodities tested. In contrast, the effect of elevated CO_2 on nutritional composition varied among the commodities and was dependent on CO_2 level and storage temperature and duration (Weichmann, 1986).

6. Hypobaric or low pressure storage (LPS): Reducing the total pressure (under partial vacuum conditions) results in reducing the

partial pressure of individual gases of air. This can be an effective method for reducing O_2 tension, and for accelerating the escape of ethylene and other volatiles. LPS has two advantages over establishing low oxygen atmospheres by other means. These are: (a) more exact control and better uniformity of O_2 concentration throughout the commodity, and (b) continuous removal of ethylene and other volatiles from the storage environment. Bangerth (1973) found that LPS was more effective than CA storage in reducing rate of ascorbic acid loss during a 28-week storage period (Table 10).

Table 10. Effect of CA and LPS on ascorbic acid in 'Golden Delicious' apples at 3°C.

Storage Time (Weeks)	mg Ascorbic Acid/100 g (FWB)		
	Control	CA	LPS
0	9.7	9.7	9.7
11	5.2	5.5	7.0
16	5.6	4.2	6.5
21	5.0	4.4	5.2
28	4.9	4.0	5.0

CA = 3% CO_2 + 4% O_2; LPS = 75 torr

Adapted from: Bangerth, 1973.

7. Sanitation procedures: Sanitation procedures throughout the postharvest handling system are essential to maximizing shelf-life of fruits and vegetables. These include: (a) cleaning of field boxes, bins, and buckets, (b) thorough scrubbing and cleaning of packinghouse machinery, (c) washing walls, floors, and ceilings of cold storage rooms with a strong detergent and a hypochlorite solution at the beginning and end of the season, (d) cleaning of transit vehicles before loading, and (e) proper disposal of refuse and cull fruits.

CONCLUSIONS

Selection of the genotype with the highest nutritional quality for a given commodity is a much more important factor than climate conditions and cultural practices in producing the best nutritional composition for that commodity at harvest. Among preharvest factors, light and temperature are the most important in determining the final vitamin content of the commodity. Factors such as rootstock used for fruit crops, amount of rainfall, soil type, irrigation and fertilization program, and mulching influence the water and nutrient supply to the plant, and, consequently affect the mineral content of plant tissues. Pruning and thinning of fruit trees determine their crop load, which affects fruit size and composition including vitamins and minerals. Other preharvest factors, such as air pollutants and the use of agricultural chemicals (pesticides, growth regulators) have a relatively minor direct effect on nutritional composition of fruits and vegetables.

Many of the harvesting and postharvest handling procedures influence the nutritional quality of fruits and vegetables. Much of the available information is about ascorbic acid which appears to be the most sensitive to postharvest losses. Additional research is needed to investigate the effects of postharvest handing procedures on nutrients other than ascorbic acid in fresh fruits and vegetables. Also, the possible effects on nutritional quality of those procedures which have not been evaluated need to be elucidated. Any new harvesting or postharvest handling method should be evaluated as to its potential impact on nutritional quality before being recommended for use.

Based on available information, the following recommendations can be made as to harvest and postharvest procedures which will maintain quality including nutritional composition of fresh fruits and vegetables:

1. Maturity and quality

   a. Harvest at the proper maturity stage relative to intended use and shipping distance.
   b. Eliminate produce with serious defects.

2. Temperature management procedures

   a. Harvest during the cool part of the day.
   b. Keep in the shade while accumulating produce in the orchard or field.
   c. Transport produce to the packinghouse or processing plant as soon as possible after harvest.
   d. Avoid delays at the packinghouse or processing plant. If delays can't be avoided, cool and hold produce at or near their optimum storage temperature until packed or processed.
   e. Ship packed produce to the market in refrigerated transit vehicles unless shipping distances and durations are short (few hours).
   f. Maintain proper temperature and relative humidity throughout the handling system between shipping point and consumption.

3. Physical damage

   a. Handle produce with care during harvesting, hauling to packinghouse or processing plant, and during packinghouse operations.
   b. Avoid drops, impacts, vibrations, and surface injuries of produce throughout the handling system.
   c. Use shipping containers which would provide adequate protection for the commodity from physical injuries.

4. Expedited handling

   a. Minimize time between harvest and retail display.
   b. Encourage direct marketing (producer to consumer) to provide fresher produce.
   c. Use fresh fruits and vegetables soon after purchase whether in the home or in restaurants and other eating places.

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